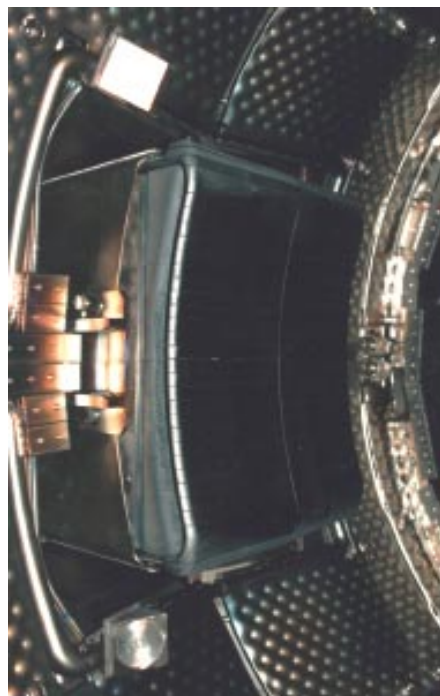


# FUSION MATERIALS

## MATERIAL EVIDENCE

Surfaces in a magnetic confinement device that are exposed to the plasma must be able to survive high temperatures, thermal cycling, neutron bombardment, and sputter erosion (which occurs when atoms are dislodged from a surface by collisions with high-energy particles). “Firebricks” that can withstand these conditions are being developed through research aimed at maximizing component lifetimes and minimizing the radioactivity induced by neutrons striking the material that faces the plasma.

This area of fusion research has produced materials and techniques that are being applied or are ready for application to other areas of materials development and analysis, manufacturing, environmental monitoring, and computing and electronics. Applications have also been found in the analysis and authentication of art objects.



Even in a stable, well-confined plasma, there is some interaction between the charged particles in the plasma and the material surfaces surrounding it. In fact, fusion devices make use of these plasma-surface interactions to remove heat introduced into the plasma by auxiliary heating or by fusion reactions, as well as excess fuel particles and helium ash.

The structures that interact with the plasma are called plasma-facing components, or PFCs. Examples include tiles that line the interior of

the vacuum vessel, or first wall; limiters, which skim off the outer edge of the plasma; and divertors, which concentrate the flux of charged exhaust particles at the plasma edge onto a small heated region called the strike point. PFCs must withstand harsh conditions, such as high heat fluxes, thermal fatigue, erosion from sputtering or plasma disruptions, loss of coolant accidents, air-steam reactions, and neutron damage. For example, the International Thermonuclear Experimental Reactor (ITER) will include an actively cooled divertor. The divertor target plate must remove a heat flux of up to 10 MW/m<sup>2</sup>. For comparison, the heat flux for the interior of a rocket nozzle is about 1 MW/m<sup>2</sup>, and that for a missile nose cone during ballistic reentry is 4 MW/m<sup>2</sup>.

Fusion researchers are addressing these issues by designing and building PFCs using materials with low atomic numbers (e.g., beryllium and carbon) to avoid plasma contamination.

The designers for ITER are considering beryllium or carbon fiber composite tiles brazed to a high-strength copper alloy. These duplex structures are being tested extensively in the laboratory. The actively cooled limiter shown at left, which

is made of pyrolytic graphite brazed to copper coolant tubes, was designed and built at Sandia National Laboratories (SNL), in collaboration with Oak Ridge National Laboratory, and is now being used on the Tore Supra tokamak in France.

Among the products of PFC research and development are carbon fiber composites that are resistant to thermal shock, plasma spray coatings of beryllium and tungsten, and improved brazing technologies for joining dissimilar materials. Carbon fiber composites whose thermal conductivity at room temperature is twice that of copper have been fabricated. Tungsten plasma spray can produce near-net-shape crucibles for manufacturing applications.

Surfaces that can selectively pump helium while releasing hydrogen were developed as the result of fusion research at SNL. The PISCES plasma arc source, which originated at the University of California in Los Angeles for laboratory simulation of plasma-materials interactions, has been applied to materials processing.

Heat removal technology from PFC development programs includes copper microchannel heat exchangers cooled by helium gas and